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The invention relates to an apparatus for the injection molding of plastic material, comprising a mold into which molten plastic material is introduced, wherein there is provided a device for introducing liquid, in particular water, into the interior of the molten material, which includes a pump driven by a motor.

Gas injection technology has been used for about 15 years on an industrial basis for the production of injection-molded hollow bodies. The gases used (generally nitrogen) however suffer from the disadvantage that process management is more difficult by virtue of the high degree of compressibility and cooling of the molten plastic material from the cavity side is not efficient, by virtue of the low heat absorption capacity of the gases.

Those disadvantages can be overcome by using liquid, in particular water, in place of a gas. In that situation, in the simplest case, the water is injected into a tool cavity which is partially filled with molten plastic material. In the first step in the process, complete shaping of the component is effected by displacement of the molten material by way of the injected water, with the simultaneous formation of the cavity in the inner core. Thereafter, the water pressure performs the post-pressure function, in a similar manner to the situation in conventional injection molding. Usually, in the pressure-holding phase, the water is held at a pressure level at which vaporization of the water is avoided. By virtue of its substantially greater specific heat the water can also absorb a considerable part of the amount of heat from the cavity side, from the molten material. If, in dependence on component geometry, in a so-called flushing process, it is possible to produce a water through-flow, the cooling time can be reduced by up to 70%, in comparison with gas injection technology.

Process variants which are known from gas injection technology such as expelling excess molten material from the inner core of a

component into a subsidiary cavity or back into the screw antechamber can also be implemented with the water injection technology.

5 Governed by historical development, the test installations which are known for water injection are structurally derived from the installations which are known for gas injection technology. In that case however by virtue of the high compressibility of the gas the nitrogen is almost exclusively injected in pressure-regulated mode. The time required for cavity formation is thus greatly dependent on the viscosity of the molten material and thermal boundary conditions. In the case of water in  
10 contrast, because of the low level of compressibility, outside the pressure-holding phases, control or regulation by way of the volume flow presents itself as an option.

15 All previously known installations involve pumps driven at a constant speed of rotation. That is not advantageous both for energy reasons and also for reason relating to wear when using a pressure-limiting valve in the by-pass (see Walter Michaeli et al, "Kühlzeit reduzieren mit der Wasser-Injektionstechnik" in KU Kunststoffe, volume 90 (2000) 8).

20 In accordance with the invention it is provided that the speed of rotation of the motor and/or the stroke or delivery volume of the pump is variable.

Details of the invention are described hereinafter with reference to the drawing in which:

25 Figure 1 is a diagrammatic view of an injection molding installation, and

Figures 2a through 2c. are three examples of regulatable motor/pump combinations.

30 The core aspect of the installation shown in Figure 1 is the mold 7, into the cavity 10 of which plastic material can be introduced in known manner.

The particular aspect of the underlying process of the invention is the introduction of water into the molten plastic material while it is setting in the mold 7. In the so-called inflation process the cavity 10 is firstly partially filled with plastic material 8, then water for industrial use which is supplied to the tank 2 by way of a conduit 7 is injected into the molten material by way of the pump 3, the shut-off valves 12 and the three-way valves 6, 6', so that a water-filled cavity 9 is formed in the molten material. When the mold is filled the set pressure is maintained by way of a pressure storage means 5. The valve 6 is then switched over to the tank conduit, a blow-out needle is pierced into the cavity 9 and the water is blow out of the cavity 9 in the interior of the plastic material 8 by a feed of air by way of the conduit 17.

Instead of the described inflation process it is also possible to execute a blow-out process which differs in that the cavity 10 is firstly completely filled with plastic material and the latter is partially transferred into a subsidiary cavity (not shown). Flushing processes are also known in which a liquid exchange takes place in the interior of the injected member during the entire procedure involving hardening of the molten material.

In all the illustrated cases, a per se known diaphragm storage means 5 is used in the pressure-holding phase. The operation of charging it up to a variable holding pressure is effected before the start of water injection.

An advantage of the described process lies in the possibility of re-using the water employed. For that purpose, it is necessary to filter the water and preferably to provide for the removal of germs from the water by means of UV-irradiation directly at the water container.

A device for deionization (desalination) of the water is installed at the automatic fresh water make-up feed for making up for losses.

The water circuits are preferably shut off directly by way of a three-way valve at or in the tool. That is particularly important as, in the previously known cases, the directional control valves are disposed in the

installation and relatively long conduit lengths are filled with air when blowing out the water. That air however is inevitably injected into the molten material in the next cycle and forms an unwanted air cushion which partially reduces the cooling effect and thus nullifies the actual  
5 advantage of water injection.

Figures 2a through 2c show examples of the way in which the energy-saving supply of water can be effected in accordance with the invention.

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The embodiment of Figure 2a has a pump 3 with a constant delivery  
10 volume. The delivery amount is controlled by varying the speed of rotation of the motor 4 which can be for example a servo motor or a three-phase asynchronous motor with frequency conversion. If instead of quantitative regulation during the holding phase pressure regulation is to be effected, then the pressure-proportional valve 11 serves for that  
15 purpose, by way of which amounts which are only minimal in comparison with the conventional by-pass flow away to the tank 2.

The embodiment of Figure 2b uses a motor involving a constant speed of rotation, for example a three-phase asynchronous motor. The pump 3 is in the form of a regulating pump. The delivery flow regulation  
20 action is effected by way of the adjustable throttle 14. If on the other hand (during a holding phase) pressure regulation is to be effected, a slight subsidiary flow goes by way of the throttle 12 and the pressure-proportional valve 11.

The embodiment of Figure 2c again uses a motor involving a  
25 constant speed of rotation, the valve 11 is a simple pressure-limiting valve and adjustment of the pump 3 is effected by way of an electrical control 15 which determines the delivery volume of the pump.